

Aerogel's for Basic Science and Application

William Halperin, Northwestern University DMR-0244099

Disordered fermion superfluids were discovered in 1995 at Cornell and Northwestern University with NSF support. We imbibe helium three liquid into highly porous silica aerogel such as shown in the picture. The new superfluid exhibits unusual properties, including new thermodynamic phases, new acoustic modes, and gapless behavior. The theory suggests the possibility of stabilizing a new type of superfluid having macroscopic anisotropy imposed by anisotropic scattering from aerogel. For this we must use an aerogel that is substantially strained in one direction. We have generated these aerogels in order to test the basic theory. These materials may also have important application to isotope purification (next page) and sorting biological molecules of different sizes.



Samples of highly porous silica aerogels are shown. The one on the left was grown at Northwestern by undergraduate student Tom Langdo. They are extremely light and almost transparent. The top of the vessel shown is an autoclave 5 inches in diameter required to super-critically dry the gels such as those that are shown.

Highly porous silica aerogel glass (98 to 99.5 % porous) has found important applications in industry, basic science, and in every day life. These fascinating materials are solid, although they are a hundred times lighter (less dense) than regular glass. Like ordinary glass however they are almost transparent as can be seen in the picture. The fact that they have a bluish cast is for the same reason that the sky is blue. Blue light is scattered preferentially since it has a short wavelength compared to red light which has a long wavelength. Just as light is scattered by aerogel so is helium when imbibed into the pore space. Helium at low temperatures condenses into a liquid which then becomes a superfluid below 0.002 mK. The properties of this unusual superfluid are the main focus of our basic scientific program. In a recent publication we show that an energy barrier called the energy gap, that exists in pure superfluids and superconductors disappears for the case of superfluid in aerogel, Choi et al. Physical Review Letters (to appear). This gapless behavior is directly demonstrated by our measurements of the heat capacity at very low temperatures. Furthermore, this basic result gives important information on what is called the density-density correlation function that describes how the porous material is organized on distances that correspond to the wavelength of visible light. Unlike most nano porous materials, aerogel can be significantly strained by squeezing in one direction. The anisotropy induced, according to the theory, should give rise to a preferential direction for scattering of either visible light, or for superfluid helium for that matter. Work is in progress to understand these effects, including contributions from graduate students, undergraduates and high school students.

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Education:

Northwestern University undergraduate Tom Lippman, Evanston Township High School student Matt Schiffman, Northwestern graduate students, Johannes Pollanen, Hyongsoon Choi, and John Davis are collaborating on aerogel physics projects in the Halperin laboratory to explore the properties of anisotropic superfluids. At right we are using aerogel for helium isotope separation. The method may have general utility to other elements. In the picture, left to right, are Choi, Johannes, Tom and John celebrating their success.

Outreach:

Matt Schiffman from the Evanston Township High School has been an intern in the Halperin laboratory for the spring and summer. He is preparing a science project (Intel Competition) demonstrating a new non-invasive technique using low frequency acoustics to monitor gelation of aerogels.

